Class VI Injection Well Application

Attachment 05: Pre-operational Testing Program
40 CFR §146.82(a)(8), 40 CFR §146.87

Stonewell Project
Marion County, Ohio

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Project Information

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Stonewell Injection Well 1 (STO INJ1) Location:

Marion County, Ohio
Latitude: 40.64989° N
Longitude: 83.23105° W

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List of Acronyms and Abbreviations

ACZ	above confining zone
APT	annulus pressure test
bpm	barrels per minute
BHA	bottomhole assembly
CO_2	carbon dioxide
CBL-VDL	cement bond log-variable density log
CFR	Code of Federal Regulations
Director	UIC Program Director
DST	drill stem test
EPA	Environmental Protection Agency
FOT	falloff test
fbgl	feet below ground level
MIT	mechanical integrity test
STO ACZ1	Stonewell Above Confining Zone Monitor Well 1
STO INJ1	Stonewell Injection Well 1
STO OBS1	Stonewell Deep Observation Well 1
STO USDW1	Stonewell USDW Monitoring Well 1
MWD	measurement while drilling
pH	acidity or alkalinity measurement
psi	pound-force per square inch
PVC	polyvinyl chloride
SRT	step-rate test
TBD	to be determined
TDS	total dissolved solids
UIC	Underground Injection Control
USDW	underground source of drinking water

1. Introduction

This document details the proposed Pre-operational Testing Program that will be implemented to characterize the chemical and physical features of the lithology at the Stonewell Project site. The formations of note include, but are not limited to, the following:

- Mt. Simon Sandstone (injection zone),
- Rome Formation (primary confining zone),
- Kerbel Formation (above confining zone (ACZ) monitoring interval),
- Lockport Dolomite (lowermost underground source of drinking water (USDW)).

The Pre-operational Testing Program laid out in this document is designed to meet the testing requirements of Title 40 (40) of the U.S. Code of Federal Regulations (CFR) Section §146.87 (40 CFR §146.87), and the well construction requirements of 40 CFR §146.86. (Attachment 01: Narrative, 2025) details the construction plan for the Stonewell Injection Well 1 (STO INJ1). This document details how the depth, thickness, mineralogy, lithology, porosity, permeability, and geomechanical information of the injection zone, confining zone, and other relevant geologic formations will be determined and verified (Figure 1, Figure 2, and Figure 3).

The Pre-operational Testing Program includes a combination of logging, coring, fluid sampling, and formation hydrogeologic testing that will be completed when the project wells are drilled. The wells to be drilled for the Stonewell Project include:

- STO INJ1
- Stonewell Deep Observation Well 1 (STO OBS1)
- Stonewell Above Confining Zone Monitor Well 1 (STO ACZ1)
- Stonewell USDW Monitoring Well 1 (STO USDW1)

Vault GSL CCS LP will notify the United States Environmental Protection Agency (EPA) 30 days ahead of the planned spud date for each of the project wells of the intent to drill, log, and test each well as well as a schedule of well logging and testing activities as per §146.87(f). An updated timeframe will be provided at least 48 hours in advance to serve as notice and provide the opportunity to witness the relevant tests or logs.

An extensive logging suite is planned for STO INJ1 to assist with characterization of the main formations of interest per §146.87. The site-specific data collected will be used to update the critical delta pressure for the site and used to update the static and computational models for the project. Geophysical logs will also be run in STO OBS1.

The Kerbel Formation will be the ACZ monitoring interval for the project (Attachment 01: Narrative, 2025).

The lowermost USDW at the Stonewell Project site is in the Lockport Dolomite, and its base is the top of the Packer Shell (Dayton Formation) (Attachment 01: Narrative, 2025) as displayed in Figure 1. The EPA defines a USDW in 40 CFR §144.3 as an aquifer with less than 10,000 total dissolved solids (TDS), measured in milligrams per liter.

Fluid samples will be collected and used to complete the baseline aqueous geochemistry for the lowermost USDW and the ACZ monitoring intervals for future comparison to monitoring data collected after injection operations begin as per §146.82(6).

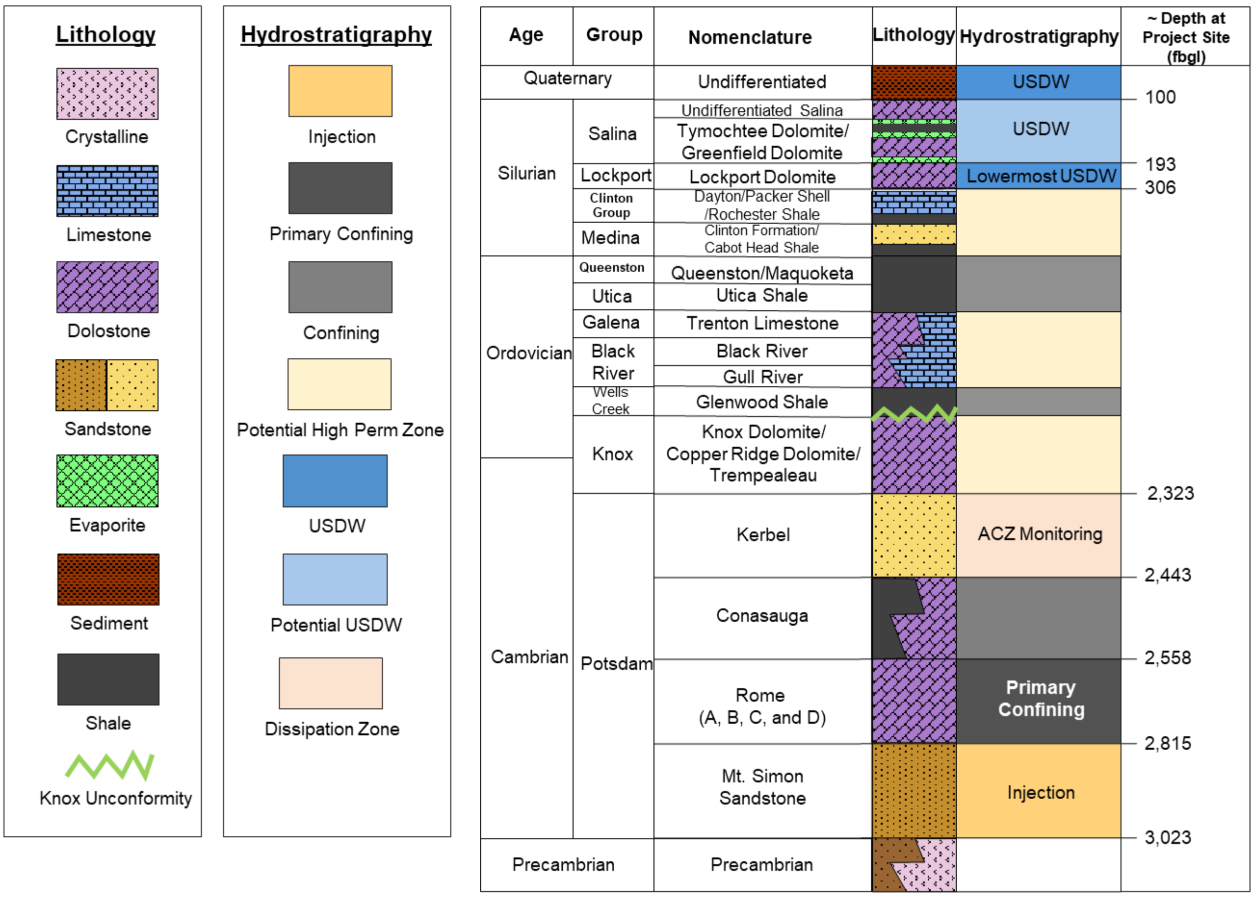

Figure 1: Site-specific stratigraphic column for project site with age, nomenclature, generalized lithology, and zone of use. (fbgl=feet below ground level)

After the data acquired in STO OBS1, STO ACZ1, and STO INJ1 has been analyzed, a Pre-operational Narrative will be submitted to the EPA that will provide the new data and the updated static and computational models that will incorporate the data from the testing program as per §146.82(c).

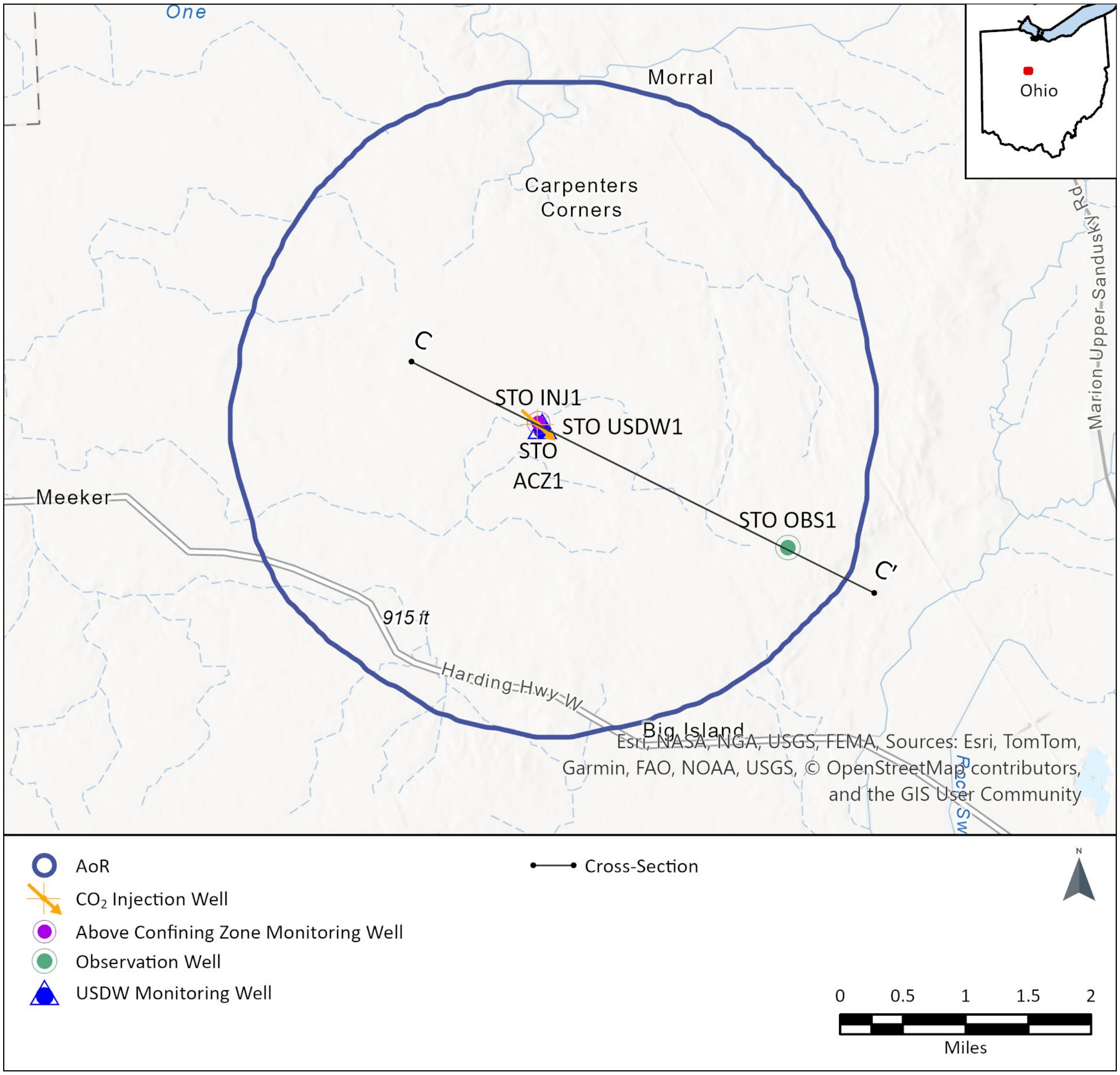

Figure 2: Site map of Stonewell Project wells with cross section C-C'.

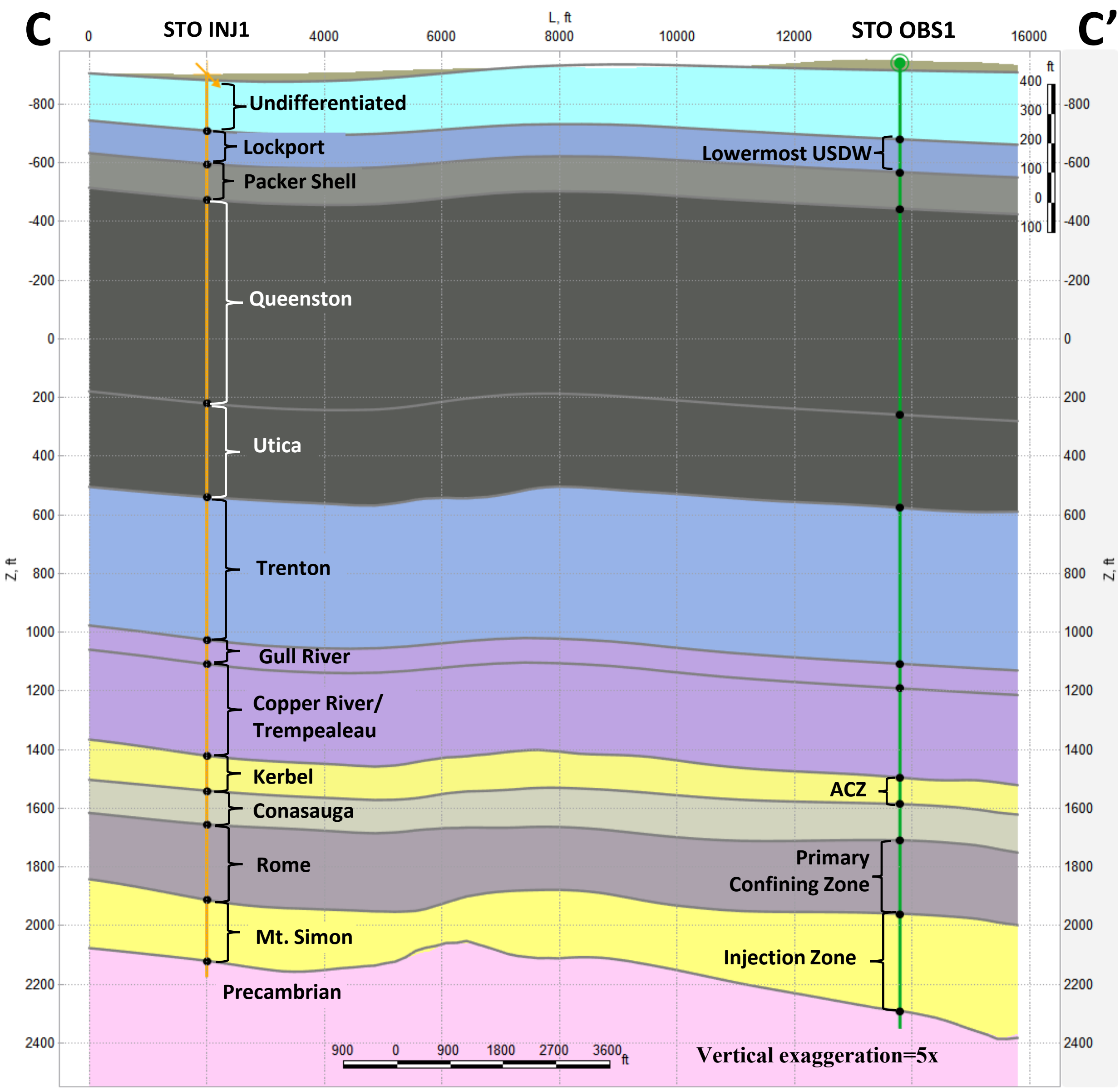

Figure 3: Cross section C-C’ (Figure 2) through the Stonewell Project wells.

2. Pre-injection Testing Plan – Lowermost USDW (40 CFR §146.87 (a))

The project will collect groundwater samples from the known USDWs within the Area of Review (AoR), which include the Silurian carbonates of the Salina Group, including the Tymochtee Dolomite/Greenfield Dolomite and the undifferentiated strata of the upper Salina Group, and the Lockport Dolomite. The Lockport Dolomite is identified by the Ohio Department of Natural Resources to be the lowermost USDW at the project site (Riley et al., 2012). The identification of the lowermost USDW will be confirmed by evaluating salinity in strata below the Lockport Dolomite through collection of water samples or resistivity logs during the drilling of project wells. Regional data indicates that the sub-Lockport strata are saline and not suitable for sources of drinking water (reference).

STO USDW1 will be used as a USDW monitoring well and will be drilled with a water well rig and completed with polyvinyl chloride (PVC) casing and PVC screening across the deepest aquifer.

To reduce the uncertainty of the depth to the Lockport Dolomite, and its relative thickness within the AoR, the lithology will be logged during the drilling of the STO USDW1, STO ACZ1, STO INJ1, and STO OBS1 wells.

To confirm the lowermost USDW, the project will attempt to collect a formation water sample from strata below the expected lowermost USDW (Lockport Dolomite).

3. Pre-injection Testing Plan – Injection Well (40 CFR §146.87 (a))

The following tests and logs will be conducted on the state-permitted stratigraphic well (Stonewell / INJ1), which is intended to be used as the Class VI injection well (STO INJ1) upon the final Class VI authorization to inject, and the hydrogeologic properties will be tested in accordance with 40 CFR §146.87(a), (b), (c), and (d). The tests and procedures are described in the section below.

STO INJ1 will be the carbon dioxide (CO_2) injection well, and the primary well used to collect pre-operational data that will include but not be limited to:

- Wireline logs, core, deep fluid samples, and well test data,
- Well integrity data that will ensure that the project wells will not serve as a conduit for CO_2 or injection zone fluid migration to the overlying USDWs.

The STO INJ1 well construction plan is presented in (Attachment 01: Narrative, 2025; Attachment 04: Injection Well Construction Plan, 2025)

3.1. Deviation Checks (40 CFR §146.87 (a)(1))

Deviation surveys will be obtained as STO INJ1, STO OBS1, and STO ACZ1 are drilled to determine the wellbore path from the surface to the total depth of the wells as per 40 CFR §146.87(a)(1). A wireline survey tool will be used to measure the inclination of the wellbore. The tool has an electronic timer that is set at the surface to allow enough time to run the tool in the drill pipe to the desired depth. Following the set time, the tool will be removed from the well, and the results will be reviewed prior to the resumption of drilling activity.

An alternative way to measure these deviation surveys is to place a measurement while drilling (MWD) tool on the bottomhole assembly (BHA) just above the drill bit. This tool records the inclination (deviation) and azimuth (direction) of the tool and then transmits this information to surface in real-time.

The planned maximum allowable deviation in the well is five degrees and surveys will be taken at the frequency shown in Table 1. If the hole deviation exceeds five degrees, the wellbore will be steered back to an acceptable deviation using directional tools such as a downhole motor or rotary steerable system added to the BHA. In general, a survey will be performed every 500 feet while drilling unless deviation of the borehole becomes apparent.

Table 1: STO INJ1 deviation survey frequencies to be taken.

Range of Deviation	Frequency of Survey
<1 degree	1 survey per every 500 feet of hole
>1 degree, but < 2 degrees	1 survey per every 250 feet of hole
>2 degrees	1 survey per every 100 feet of hole

3.2. Tests and Logs

3.2.1. Tests and Logs Performed During Drilling

3.2.1.1. Well Logging

Table 2 and Figure 4 summarize the type and purpose of each well log that the Stonewell Project proposes to acquire in the surface, intermediate, and long string casing segments of the well as per 40 CFR §146.87(2)(i) and (3)(i).

In addition to the well logs listed in Table 2, the project may run other specialty well logs over the injection zone and confining interval to further characterize these formations. Specialty logs may include, but are not limited to, elemental capture spectroscopy, dipole sonic in multiple modes, or zero offset vertical seismic profiles.

Table 2: STO INJ1 summary of the open hole wireline logs and associated parameters of logging tools to be run for each well segment.

Log	Log Type	Parameters Obtained	Surface	Intermediate	Long
Open hole logging	Gamma ray	Lithology	x	x	x
	Density	Porosity, density	-	x	x
	Neutron porosity	Porosity	-	x	x
	Spontaneous potential	Permeability	x	x	x
	Resistivity	Fluid saturation, permeability	x	x	x
	Caliper	Borehole diameter, stress	x	x	x
	Image log	Lithology, porosity, borehole diameter, fracture characterization, stress	-	-	x[1]
[1] Log will be run over the ACZ monitoring, primary confining, and injection zones.					

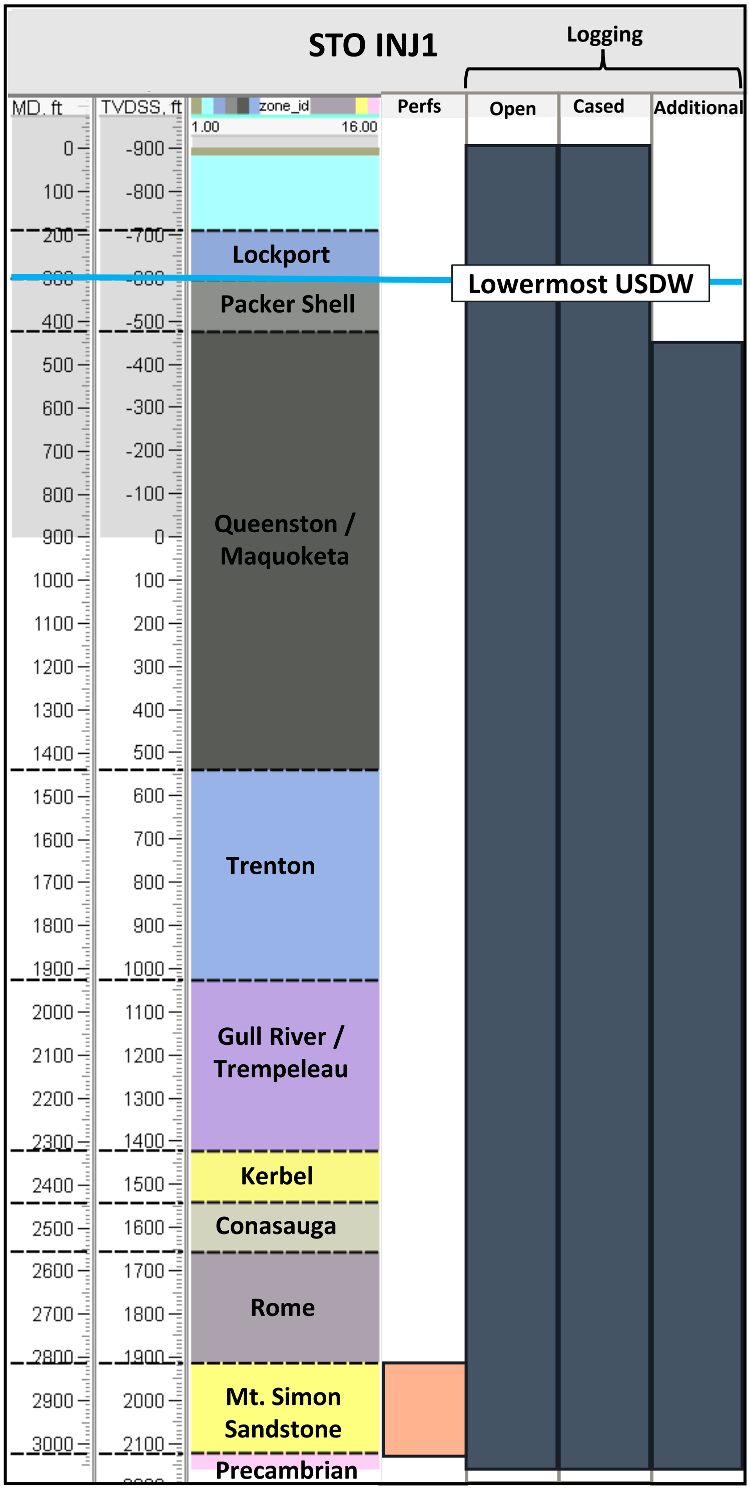

Figure 4: STO INJ1 summary of wireline logs and associated parameters of logging tools to be acquired before and after casing is installed. "Additional" indicates logs in addition to the logs required by 40 CFR §146.87(a). (MD=measured depth, TVDSS=true vertical depth below sea level)

3.2.1.2. STO INJ1 Well Core Program (40 CFR §146.87 (b)(d))

Up to 60 feet of core will be acquired in the primary confining zone (Rome Formation) and up to 60 feet in the Mt. Simon Sandstone as per 40 CFR §146.87(b). The core will provide a visual evaluation of facies and lithologic heterogeneity and will undergo routine core analyses and selected special core analyses such as for determining geomechanical parameters and mercury injection capillary pressure (MICP) curves. The whole cores from the primary confining zone and injection zone may be augmented by additional side wall coring if the project is not able to obtain the desired whole core intervals or to cover other specific zones of interest. Table 3 summarizes the plans for whole core acquisition and contingent sidewall core from STO INJ1. Table 4 identifies the analyses to be performed on core samples along with the parameters measured and target formations. Detailed plans for core acquisition and analysis will be provided prior to well installation.

Table 3: Whole core collection plan.

Core Type	Target Interval MD (feet)	Formation	Core Size
Whole Core	Up to 60 feet	Rome Formation	4-inch
Whole Core	Up to 60 feet	Mt. Simon Sandstone	4-inch
Sidewall Core	Contingency	As Needed	1.5-inch
Note: Whole core plugs will be taken from the whole core at regular intervals. Sidewall core collection will be contingent on the results of the well logging and the success of the whole core acquisition.			

Additional core will be collected if:

- Interpretated well data indicates that additional data are needed to meet Class VI permit requirements.
- As required by the Underground Injection Control (UIC) Program Director (Director).

Core samples from STO INJ1 will provide site specific information regarding geologic properties. Laboratory analyses of the core will be integrated with wireline logs and used for petrophysical calibration. The integrated dataset will be correlated with wireline logs from offset wells to evaluate lithologic heterogeneity and confirm stratigraphy and rock properties.

Core acquisition and analysis plans will be provided once finalized with a coring contractor prior to well installation (Table 4).

Table 4: Summary of potential core analyses and associated parameters

Core Analysis Type	Parameters Obtained	Formations
Core description	Thickness, grain size, sedimentary structures, geologic contacts	Mt. Simon Sandstone Rome Formation Intervals to be determined (TBD)
Routine core analysis	Porosity, permeability, grain density	Mt. Simon Sandstone Rome Formation Intervals TBD
Thin-section petrography	Mineralogy, lithology, porosity, grain size, textural maturity, oil staining	Mt. Simon Sandstone Rome Formation Intervals TBD
X-ray diffraction	Mineralogy, clay identification	Mt. Simon Sandstone Rome Formation Intervals TBD
Core gamma ray log	Lithology, porosity, grain size, geologic contacts	Mt. Simon Sandstone Rome Formation Intervals TBD
Relative permeability	Relative permeability, wettability	Mt. Simon Sandstone Intervals TBD
Mercury injection capillary pressure	Capillary pressure	Mt. Simon Sandstone Rome Formation Intervals TBD
Triaxial tests	Rock strength, ductility, Poisson's Ratio, Young's Modulus	Mt. Simon Sandstone Rome Formation Intervals TBD
Rock compressibility	Rock compressibility	Mt. Simon Sandstone Rome Formation Intervals TBD

3.2.2. Tests and Logs Performed During and After Casing Installation *(40 CFR §146.87 (a)(2), (3))*

3.2.2.1. Well Logging

Table 5 summarizes the cased hole well logs that will be acquired after casing is set and cemented for each well section as per 40 CFR §146.87(a)(2)(ii) and (a)(3)(ii). The bottom of the surface casing will be set at approximately 346 fbgl as per Attachment 01: Narrative (2025). As per 40 CFR §146.87(a)(2)(ii) a cement bond, variable density log, and temperature log will be collected after surface casing is set. Intermediate casing will be installed in the injection well and set at approximately 2,101 feet. Long string casing will be set at approximately 3,063 fbgl, which is approximately 40 ft below the top of the Precambrian Basement (Attachment 01: Narrative, 2025). A 10-foot rathole is planned for all sections of the well, so the bottom of the casing will be approximately 10 feet shallower than the bottom of the hole section.

Table 5: STO INJ1 summary of cased hole wireline logs and parameters of tools.

Log	Log Type	Parameters Obtained	Surface	Intermediate	Long
Cased hole logging (required)	Cement bond log-variable density log (CBL-VDL)	Cement integrity, external mechanical integrity	x	x	x
	Temperature	Temperature profile	x	x	x
Cased hole logging (additional)	Ultrasonic cement evaluation	Cement integrity, external mechanical integrity	-	x	x
	Pulsed neutron	Lithology, baseline fluid saturation, porosity	-	x	x

3.2.2.2. Fluid Sampling and Analysis (40 CFR §146.87 (b – d))

The characterization of injection zone fluids will be based on analysis of fluid samples acquired from STO INJ1 or STO OBS1 as per 40 CFR §146.87(b). These samples will be collected through swabbing, drill stem tests (DSTs), or downhole pumps and will provide information on the baseline aqueous geochemistry of the injection zone fluids. The fluid samples will be analyzed for TDS and major analytes including isotope analysis (Table 6). Isotope analysis will be completed for fluid samples acquired from the ACZ and lowermost USDW formations obtained in project wells. The static fluid level of the injection zone will also be established in STO INJ1.

Table 6: Summary of analytical and field parameters for groundwater samples

Parameters	Analytical Methods [1]
Cations: Ca, Fe, K, Mg, Na, Si	EPA 6010B
Cations: Al, Sb, As, Ba, Cd, Cr, Cu, Pb, Mn, Hg, Se, Tl	EPA 200.8, EPA 245.1
Anions: Br, Cl, F, NO_3, and SO_4	EPA 300.0
Alkalinity	SM 2320B
TDS	SM 2540C
Total Organic Carbon	SM 5310C
Dissolved Inorganic Carbon	SM 5310C
Total and Dissolved CO_2	ASTM D513-06B
Stable Isotopes of δ13C	Isotope Ratio Mass Spectrometry [2]
Acidity or alkalinity measurement (pH)	Field with multi-probe system
Conductivity/Resistivity	Field with multi-probe system
Temperature	Field with multi-probe system

[1] An equivalent method may be employed with the prior approval of the Director.

[2] Gas evolution technique by Atekwana and Krishnamurthy (1998) with modifications made by Hackley et al. (2007)

The formation water chemistry and mineralogical data obtained from core and well logging of the injection zone and primary confining zone will be used to update geochemical modeling described in the Narrative (Attachment 01: Narrative, 2025) to confirm potential reaction pathways resulting from injected CO_2. These analyses will indicate the compatibility of the CO_2 stream with fluids in the injection zone and the minerals of the injection and confining zone as per 40 CFR §146.82(c)(3). These analyses will also identify if there are components of the injection zone mineralogy that have the potential to release trace metals through dissolution resulting from injection.

In addition, well log and core data will be used to evaluate mineralogical components and heterogeneity within the injection and primary confining zones and to identify facies variations. The impact that facies variations and heterogeneity may have on mineral reactions and the resultant confining zone characteristics will be assessed during the Pre-operational Testing Program as per 40 CFR §146.82(a)(3)(iii) and 40 CFR §146.84(c)(1)(i) and (ii). Additional data that may supplement these assessments include image logs and 3D surface seismic data.

The compatibility of the well cement and the CO_2 stream will be evaluated based on injection zone fluid compositions and pressure and temperature characteristics as per 40 CFR §146.86. The well logging and fluid sampling programs described in this Pre-operational Testing Program are designed to:

- Determine the salinity in relevant geologic formations, such as the lowermost USDW, ACZ interval, and injection zone,
- Ensure conformance of injection well construction requirements (40 CFR §146.86),
- Establish baseline data that can be used for comparison against future measurements if they are needed as per 40 CFR §146.87(a).

3.2.2.3. Step-Rate Testing (40 CFR §146.87 (d)(1))

Step-rate testing is a primary method of determining fracture pressure as per 40 CFR §146.87(d)(1) and contributes to the geomechanical characterization of the injection site as described in Section 2.7 *Geomechanical and Petrophysical Information* of the (Attachment 01: Narrative, 2025). The geomechanical data collect will be used to determine the vertical stress and maximum and minimum horizontal stresses as per 40 CFR §146.82(a)(3)(iv) in addition to the fracture gradient.

An SRT will be performed on the injection zone interval in STO INJ1 through the analysis of the pressure response to increases in injection rates to determine the following information:

- Fracture opening pressure (to determine the fracture gradient),
- Fracture propagation pressure,
- Fracture closure pressure.

Injection at each step rate will be performed STO INJ1for the same period as detailed in the high-level procedure below. A formal procedure will be provided to the EPA prior to performing the SRT.

1. Record downhole static pressure and temperature for a minimum of one hour.
2. Rig-up pump truck, ensure sufficient volume of fluid is present at location to begin testing.
3. Pressure test lines above maximum anticipated operating pressure, but below equipment rating.
4. Begin SRT.
   a. Pump first step of test at first desired rate (e.g., 0.5 barrels per minute [bpm]) for a defined time (e.g., 0.5 hours).
   b. After the first step is completed, increase rate to next step (e.g., 1.0 bpm) for the same defined step time (0.5 hours).
   c. Repeat until the end of the test.
5. Shut-in well at the wing valve(s). Record the time of shut-in, the rate prior to shut-in and the instantaneous shut-in pressure.
6. Rig-down pump truck.
7. Monitor pressure falloff for minimum of 24-hours.

Data from the SRT will be analyzed and interpreted, and the results, along with gauge calibration records, will be included in the post installation reporting.

3.2.3. Demonstration of Mechanical Integrity (40 CFR §146.87 (a)(4))

Table 7 summarizes the mechanical integrity tests (MITs) that may be used to demonstrate the integrity of the injection well as per 40 CFR §146.87(a)(4).

Table 7: Pre-operational mechanical integrity testing schedule for the injection well.

Class VI Rule Citation	Rule Description	Test Description	Program Period
40 CFR §146.89(a)(1)	MIT - Internal	Annulus pressure test (APT)	Following initial completion
40 CFR §146.87(a)(4)	MIT - External	Temperature log	Following initial completion
40 CFR §146.87(a)(4)	MIT - External	CBL-VDL	During initial completion
40 CFR §146.87(a)(4)	MIT - External	Ultrasonic Cement Evaluation	During initial completion

Vault GSL CCS LP will notify EPA at least 30 days prior to conducting the test and provide a detailed description of the testing procedure. Notice and the opportunity to witness these tests or logging shall be provided to EPA at least 48 hours in advance of a given test or logging run.

3.2.3.1. Internal Mechanical Integrity Testing (40 CFR §146.87 (a)(4)(i))

Internal mechanical integrity refers to the integrity of the seal between the long string casing, tubing, wellhead, and packer as well as the integrity of the individual components. In this subsection, the annulus refers to the casing-tubing annulus. The effectiveness of this seal can be confirmed with an annulus pressure test (APT) and annular pressure monitoring.

Internal mechanical integrity will be demonstrated using an APT as is standard for Underground Injection Control (UIC) wells. Prior to the installation of the wellhead, the annulus will be filled with fluid as outlined in the Well Construction section of the Project Narrative (Attachment 01: Narrative, 2025). A baseline APT will be performed to 1,500 pound-force per square inch (psi) after the tubing, packer, downhole equipment, and the wellhead have been installed as outlined in Attachment 01: Narrative (2025) and in Section 6 *APT Procedures*. The maximum operating pressure for the annulus is 1,500 psi. The APT procedures for the injection well are given in Section 6.1 *STO INJ1*.

In addition to the APT, the tubing will be inspected during installation to monitor for corrosion. Once injection commences, injection pressure, annular pressure, and annular fluid volumes will be monitored continuously to ensure internal well integrity and that proper annular pressure is maintained (Attachment 06: Testing and Monitoring, 2025).

3.2.3.2. External Mechanical Integrity Testing (40 CFR §146.87 (a)(4)(ii – iv))

External mechanical integrity refers to the absence of fluid movement through channels in the cement between the long string casing and the borehole. The external integrity of STO INJ1 and STO OBS1 will be monitored through the life of the project wells on the schedule provided in (Attachment 06: Testing and Monitoring, 2025). Generally accepted methods for evaluating external mechanical integrity include:

- Temperature or noise log, and
- Oxygen-activation logging (during operation).

After completion, a baseline temperature log will be run from surface to the bottom of the long string casing to establish the initial temperature along the well. Temperature logging will be performed at regular intervals during the injection phase of the project based on the schedule provided in the Testing and Monitoring Plan (Attachment 06: Testing and Monitoring, 2025). The results of the temperature logs will be compared to the baseline log to look for indications of anomalous upward fluid migration. If the temperature logging data suggest that an issue with external well integrity exists, more detailed logging, such as oxygen activation or noise logs, will be performed.

In addition to the baseline temperature log, a cement bond log-variable density log (CBL-VDL), an advanced ultrasonic cement evaluation log, will be run across the intermediate and long string casing after completion of the injection well to confirm the integrity of the cement between the casing and the formation (Table 5). CBL-VDLs are recorded with sonic tools that detect the bond of the casing and formation to the cement and identify potential damage or channels in the cement.

4. Pre-injection Testing Plan – STO OBS1 (40 CFR §146.87 (a))

STO OBS1 will be logged to establish depths to formation tops. The deep observation well will also be used to confirm that the Kerbel Formation will provide a suitable ACZ monitoring interval. Intermediate casing will be installed in the well in the event that lost circulation zones are encountered when the well is drilled, as such logging runs in the intermediate casing string have been labeled as contingency.

4.1. Deviation Checks (40 CFR §146.87 (a)(1))

Deviation surveys will be obtained as the observation well is drilled, following the procedure outlined in Section 3.1 *Deviation Checks*.

4.2. Tests and Logs

4.2.1. Tests and Logs Performed During Drilling

Table 8 summarizes the open hole logs that will be acquired before casing has been set for the surface, intermediate, and long string casing, as well as the purpose of each well log as per 40 CFR §146.87(a)(2)(i) and (3)(i). Long string casing will be set at approximately 3,313 fbgl, which is approximately 80 ft below the top of the Precambrian Basement. A 10-foot rathole is planned for all sections of the well, so the bottom of the casing will be approximately 10 feet shallower than the bottom of the hole section.

Table 8: STO OBS1 summary of open hole wireline logs and associated parameters of tools.

Log	Log Type	Parameters Obtained	Surface	Intermediate (contingency)	Long
Open hole logging	Gamma Ray	Lithology	-	x	x
	Density	Porosity, density	-	x	x
	Neutron Porosity	Porosity	-	x	x
	Spontaneous Potential	Permeability	-	x	x
	Resistivity	Fluid saturation, permeability	-	x	x
	Caliper	Borehole diameter, stress	-	x	x

4.2.2. Tests and Logs Performed During and After Casing Installation

Table 9 summarizes the cased hole logs that will be run after casing has been set for the surface, intermediate, and long string casing, as well as the purpose of each well log.

Table 9: STO OBS1 summary of cased hole wireline logs and associated parameters of tools.

Log	Log Type	Parameters Obtained	Surface	Intermediate (contingency)	Long
Cased hole logging (required)	CBL-VDLs	Cement integrity, external mechanical integrity	x	x	x
	Temperature	Temperature profile	x	x	x
Cased hole logging (additional)	Ultrasonic cement evaluation	Cement integrity, external mechanical integrity	-	-	x
	Pulsed neutron	Lithology, baseline fluid saturation, porosity	-	-	x

4.2.3. Demonstration of Mechanical Integrity (40 CFR §146.87 (a)(4))

Table 10 summarizes the MITs to be performed on the deep observation well after installation and prior to commencing CO_2 injection operations:

Table 10: Pre-operational mechanical integrity testing schedule for the deep observation well

Test Name	Test Description	Program Period
MIT - Internal	APT	Following initial completion
MIT - External	Temperature log	Following initial completion
MIT - External	CBL-VDL	During initial completion
MIT - External	Ultrasonic Cement Evaluation	During initial completion

Notice and the opportunity to witness the test/log shall be provided to EPA at least 48 hours in advance of a given test/log. Note that the APT will be run to 500 psi.

5. Pre-injection Testing Plan - ACZ Monitoring Well (40 CFR §146.87 (a))

5.1. Deviation Checks (40 CFR §146.87 (a)(1))

Deviation surveys will be obtained as the ACZ well is drilled and will follow the procedure outlined in Section 3.1 *Deviation Checks*.

5.2. Tests and Logs

5.2.1. Tests and Logs Performed During Drilling

Open hole gamma ray and caliper logs will be run in the STO ACZ1 surface and long string casing sections before casing is set (Table 11).

In STO USDW1 and STO ACZ1, cuttings will be collected to help identify shallow USDW formation tops where cores and logging are not feasible or planned.

Table 11: STO ACZ1 summary of wireline logs and associated parameters of tools.

Log	Log Type	Parameters Obtained	Surface	Long
Open hole Logging	Gamma Ray	Lithology	x	x
	Caliper	Borehole diameter, stress	x	x
Cased hole logging (Required)	CBL-VDL	Cement integrity, external mechanical integrity	x	x
	Temperature	Temperature profile	x	x

5.2.2. Tests and Logs Performed During and After Casing Installation

Cased hole logs will be acquired in STO ACZ1 to assess cement integrity and obtain baseline logs for future reference (Table 11).

Fluid samples will be acquired from the ACZ (Kerbel Formation) in STO ACZ1 to characterize the baseline aqueous geochemistry of the ACZ monitoring zone for comparison to future monitoring data. The formation water samples will be collected through swabbing, DSTs, or downhole pumps and will be analyzed for TDS and major analytes (Table 6). The static fluid level of the ACZ monitoring zone will also be established in STO ACZ1.

5.2.3. Demonstration of Mechanical Integrity (40 CFR §146.87 (a)(4))

Table 12 summarizes the MITs to be performed on the ACZ monitoring well after installation and prior to commencing CO_2 injection operations:

Table 12: Pre-operational mechanical integrity testing schedule for the ACZ monitoring well

Test Name	Test Description	Program Period
MIT - Internal	Casing pressure test	Following initial completion, prior to perforating ACZ interval
MIT - External	Temperature log	Following initial completion
MIT - External	CBL-VDL	During initial completion

Notice and the opportunity to witness the test/log shall be provided to EPA at least 48 hours in advance of a given test/log.

6. APT Procedures

6.1. STO INJ1

An APT will be performed after the initial well completion for STO INJ1. The annulus will be filled with a non-corrosive fluid and additives.

The APT will be performed to demonstrate internal mechanical integrity following the initial completion of the well. The test will be performed consistent with approved and accepted guidance and regulations (40 CFR §146.89 (b)).

The following procedure will be followed for all APTs conducted:

1. Install a calibrated digital gauge on the casing-tubing annulus. Note initial pressures on the tubing and annulus.
2. Ensure the well is in thermal equilibrium. Thermal equilibrium will be assumed under the following circumstances:
   a. Injection has not occurred for approximately 24 hours, or sufficient data indicates the wellbore temperature is static. The scenario constitutes a static APT.
   b. Injection is occurring at a constant rate (±5%), often referred to as a dynamic APT.
3. Identify initial system fluid level and then increase annulus pressure to 1,500 psi.
4. Disconnect the annulus system and ensure the annulus is isolated.
5. Monitor the annulus and tubing pressure for a period of not less than one-hour, taking readings every 10-minutes.
6. Once the test has concluded, reconnect the annulus system.
7. Blow the pressure down to the normal operating pressure.

6.2. STO OBS1

Following the completion and installation of tubing in the STO OBS1 well, an APT will be performed after initial well completion following the procedure provided in Section 6.1 *STO INJ1*. The annulus will be pressured to 500 psi for the APT.

6.3. STO ACZ1

An APT will be performed on the STO ACZ1 after the initial well completion and prior to the perforation of the well. This test will provide an indication of the integrity of the casing-wellhead seal and casing integrity.

The procedure outlined below will be followed to perform the test:

1. Install calibrated digital gauge on the wellhead. Note initial pressures.
2. Increase pressure to 500 psi.
3. Monitor the pressure for a period of one-hour, taking readings every 10-minutes.
4. Once the test has concluded, blow the pressure down to the pre-test pressure.

7. Pressure Fall-Off Test Procedures (40 CFR §146.87 (e))

A pressure falloff test (FOT) will be run on STO INJ1. The purpose of this test is to further characterize the hydrogeologic characteristics of the injection zone. During this test, fluid will be injected at a constant rate for a predetermined length of time, after which the well will be shut in, and the pressure monitored for an equal period of time. Injection zone pressure will be measured as part of the FOT as per 40 CFR §146.82(c). The static fluid level of the injection zone will be determined either after the well completion or after the FOT as per 40 CFR §146.82(c) pending scheduling of well service providers.

The data from this test will be evaluated using rate superposition analysis to determine injection zone information such as permeability, skin factor (damage), and flow regimes present. This analysis will act as a baseline measurement to determine the change in overall effectiveness and injectivity of the injection zone over time. These tests will also help evaluate whether the presence of any structural features in the injection zone, such as faults, are transmissive or present a barrier to flow. A high-level procedure has been provided below:

1. Record static bottomhole pressure and temperature for a minimum of one hour.
2. Rig-up pump truck, ensure sufficient volume of fluid is present at location to begin testing.
3. Begin injection. Inject at constant rate for predetermined duration.
4. At the end of the injection period, shut the well in at the wing-valve(s). Record the time of shut-in, rate prior to shut-in, and the shut-in pressure.
5. Secure the well.
6. Rig-down pump truck.
7. After the pressure has been allowed to decline for approximately the same duration as the injection the test can conclude.

A formal procedure will be provided to the EPA prior to running the FOT.

8. Characterization of Subsurface Faults and Stress

The geomechanical characterization of the injection and confining zones for the project will be assessed by analyzing one or more of the following data sets: core analyses, log data, and in-situ field tests. These analyses may include, but are not limited to, triaxial compressive strength tests of core samples, dipole sonic and image logs, and SRT. The data collected will be used to determine the vertical stress and maximum horizontal and minimum horizontal stresses at the project site as per 40 CFR §146.82(a)(3)(iv), in addition to the fracture gradient. Samples or measurements for geomechanical evaluation may be collected from STO INJ1and STO OBS1.

A 3D surface seismic survey will be conducted as part of the Pre-operational Testing Program to:

- Augment the existing 2D surface seismic survey,
- Evaluate the presence of faults or structural features,
- Determine the potential impact of faults or structural features on injection or containment,
- Confirm that the siting criteria of 40 CFR §146.83(a)(3)(ii) is being met.

The 3D surface seismic survey will provide an assessment of the orientation, geometry, depth, and displacement of structural features including the Precambrian topography and allow a re-evaluation of faults as interpreted using 2D surface seismic data. This 3D surface seismic data will be used to characterize any potential basement faults, faults that may transect the injection zone, and how such faults are positioned relative to the CO_2 plume and pressure front.

Any faults identified in the AoR will be included in the static modeling. If a fault is identified in the injection zone with the 3D surface seismic data, pressure fall-off tests may be able to determine if the feature is transmissive or a barrier to flow. The geomechanical data will be used to refine the magnitudes and orientations of subsurface stresses and used to evaluate fault stability and potential fault re-activation in the AoR. Pressure thresholds will be assessed to provide evidence for fault stability and the potential for induced seismicity as per 40 CFR §146.82(a)(3)(ii). The mineralogical and facies data will be combined with the geomechanical data to confirm fault sealing characteristics in the Rome Formation confining zone as per 40 CFR §146.82(a)(3)(ii).

The 3D surface seismic survey and any identified structural features will be integrated into updated static and computational models with all the new site-specific data gathered from STO INJ1 and STO OBS1 wells. The results from the updated computational model simulation will be compared to the results of the original permit model and used to verify the project AoR.

Financial responsibility demonstration prior to injection will consider the potential for fluid migration along faults or fractures based on the evaluation of site-specific seismic and geological data.

9. References

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Attachment 01: Narrative, 2025, Underground Injection Control Class VI Permit Application: Stonewell.

Attachment 04: Injection Well Construction Plan, 2025, Underground Injection Control Class VI Permit Application: Stonewell.

Attachment 06: Testing and Monitoring, 2025, Underground Injection Control Class VI Permit Application: Stonewell.

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